2021 AIAA Aviation Forum: eVTOL & eSTOL - Competitors or Complements?

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Vertiport Planning is at a Critical Stage of Development

FAA is adapting AC 150 Heliport Design Guidance to include eVTOL diff
NFPA is developing fire safety standards for Vertiports
NASA is developing operational procedures for High Density Operations
Real Estate Investors are leasing/purchasing properties
City Planning Departments will soon be wrestling with site approvals
Initial infrastructure will be ready by 2024 in select cities
UAM/eVTOL market cannot progress without infrastructure

eSTOL Developers are Claiming Potential Use of eVTOL Vertiports

eSTOL claims of 100’ ground roll and 300’ balanced field length
Are these claims realistic?
Is it feasible for eSTOL to claim use of future Vertiports?
Does eSTOL need to be included in Vertiport standards?

WHY THIS DISCUSSION MATTERS

Infrastructure drives the future of eVTOL and eSTOL

With eSTOL you get...

1. More payload and range
2. Lower noise
3. 60% lower operating costs
4. 70% lower development cost
5. Lower certification risk

... compared with eVTOL
Prior eSTOL Technology and Concept Development

I was an eSTOL zealot with the same goal of 100’ ground roll and 300’ field length

Came up with many wild concepts, none could address the severe challenges

Extreme eSTOL (100’ ground roll) challenges include:

**Aircraft Design Challenges**
- CLmax of ~10 required to achieve Vapproach with a 1.3 Vstall margin to achieve takeoff distance
- CLmax requires high induced velocities from propellers, not compatible with low discladding thrust optimized propellers
- Propellers are smaller diameter, resulting in mid frequency tonal content where human hearing is most sensitive
- Creating sufficient drag during approach (while creating powered lift)
- Cruise efficiency wants large span, but Vapproach wind gust tip stall upset risk and approach drag want a short span

**Operations Challenges**
- Abort capability until final touchdown (without being on backside of power curve)
- Perform tight turns through departure and approach without tip stall
- Aircraft attitude angle during approach of 20 to 30 deg nose down
- Maintaining lift and control with tailwinds, crosswinds and gusts at Vapproach of 30 mph (with a directional runway)
- High turbulence environment from surrounding buildings in urban areas
- Straight Right of Way of 1200’ before and after infrastructure location with 12 deg glideslope before clearing 500’ height

MY EXPERIENCE

For many years, I tried to make eSTOL viable
NASA LeapTech showed exactly what DEP can do for eSTOL

Inspired by Wills Wings and Scaled Composites pickup truck “wind tunnel” testing

First full-scale Distributed Electric Propulsion (DEP) wing built and “flight” tested, validating our claims

With ~300 hp of DEP and a Fowler flap, achieved $CL_{\text{max}} \sim 5.5$, with minor pitching moment!

Propellers were designed for high induced velocity for $CL_{\text{max}}$ (not thrust)

Follow on X-57 asked what we can do with this new high lift capability
Max Power: 18 shp/prop
Co-rotating propellers
\( V = 73 \text{mph}, \text{AoA} = 9^\circ \)

Wing Alone (with Fowler Flap Extended)
eSTOL vs. eVTOL noise

LeapTech Propeller compared to an eVTOL Propeller

Similar tip speeds for both LeapTech and eVTOL propellers

eVTOL propeller produces ~500 lb thrust

eSTOL propeller produces ~50 lb thrust

eVTOL is 8 dB lower, but sounds 20-30 dB lower!

It’s not just about how much noise you make, but what frequency (and quality) of noise
PERFORMANCE

100’ takeoff roll with wingborne flight

Assumptions

Thrust / Weight and Axial Acceleration = 0.4

Wingloading = 20 lb/ft², Resulting in a Vcruise = 150 mph

Vstall = 23 mph

Vapproach = 1.3 * Vstall = 30 mph

CLapproach required = 6.2

CLmax required = 10.5 (unless FAA agrees to a lower margin)

Glide path = 12 deg results in 2700’ approach/departure corridor before clearing 500’ altitude
Real infrastructure inhibits practical eSTOL operation at scale
CONCLUSION

DEP is enabling, but needs the right market fit

DEP is an Amazing Technology Offering New Capabilities

Instead of using higher CLmax for STOL, NASA X-57 used CLmax to decrease wing area

Increases wingloading from 23.5 lb/ft² to 60 lb/ft², which increases high speed cruise Lift/Drag ratio from 10-11 to 16-18

Higher wingloading also provides improved safety, ride quality and gust response

DEP has a greater opportunity to improve eCTOL for Regional Air Mobility

Economics matter, eCTOL DOC < eSTOL DOC < eVTOL DOC

And U.S. has 5,000 public use airports available for eCTOL that are barely being used...

eSTOL Market Fit

eSTOL and eVTOL require fundamentally different infrastructure

LeapTech-like DEP implementations can achieve 600’ field lengths at equivalent wingloading

Traditionally STOL has only been successful in developing countries (e.g. Africa)

- Don’t have existing General Aviation airfields (typically 3,000’ field length)
- Don’t have as severe of urban area constraints